崇新学堂

2024 — 2025 学年第一学期

实验报告

课程名称：Introduction to EECS Lab

实验名称：DL8 - Turning Heads

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DL8 - Turning Heads

1. Introduction

Design Lab 8 is dedicated to the design and demonstration of circuits aimed at controlling motor speed. This lab builds upon the motor model introduced in Homework 2 and the proportional controller explored in Design Lab 6 (and earlier), culminating in a straightforward feedback system that directs the robot head's photoresistive eyes toward an incident light source.

- Characterization of the Lego motor utilized in the robot head
- Buffering the voltage supplied to drive the motor using an operational amplifier
- Designing a simple bi-directional speed controller
- Demonstrating a feedback system that enables the robot head to orient itself towards light, employing a robotic brain to control the motor

2. Experimental step

Step 1:

The motor is designed to be driven with a voltage difference between 0 and 10 V across its terminals.

• Connect the power supply terminals labeled +15 V and GND to the power rails of our separate proto board using clip leads.Adjust the power supply voltage to 0 V.

• Plug a 6-pin connector into the proto board and connect it to a standalone motor.

• Turn off the power supply; wire pins 5 and 6 of the connector to the power and ground rails, respectively, of the proto board.

• Turn on the power supply.

• Connect a multimeter to measure the voltage from the power supply.

• Adjust the power supply voltage between 0 and 10 V and note the relation between motor speed and applied voltage.

• Swap the connections to power and ground. What happens?

• What is the minimum voltage required to make the motor turn?

V(min) = 0.4V

Step 2:

• Remove the connection between the motor and power rails of the proto board.

• Re-adjust the power supply back to +10 V, then turn it off.

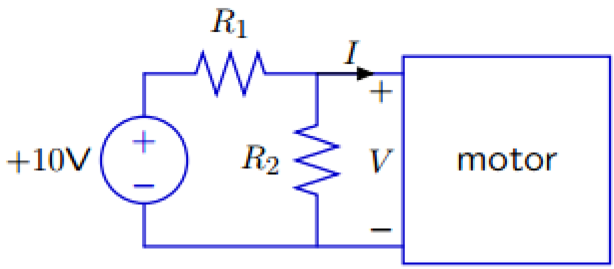
• Measure the resistance rm of the disconnected motor using the multimeter.

r(m) =6.3Ω

1.2 Controlling the motor with resistors

Our goal is to control the motor electronically. We will ultimately mount the motor on the robot and use the robot's power supply, which is constant at 10 V. The point of this section is to find a way to use a constant-voltage power supply to get a range of motor speeds.

Consider the following resistor circuit for generating the control voltage, where R1 = R2 = 1000Ω.



Step 3:

Build the circuit on our proto board. Turn the power supply back on and measure the voltage across the motor and observe the motor's behavior.

V(motor) =0.05V

Check Yourself 1

Does the motor turn? Explain.

The motor cannot rotate because the motor voltage is 0.0522 less than the rotation threshold voltage of 0.4.

Step 4:

Use circuit theory, treating the motor as a resistor, to determine the voltage across the motor. Use the resistance value we measured in step 2.

Vmotor =0.062V

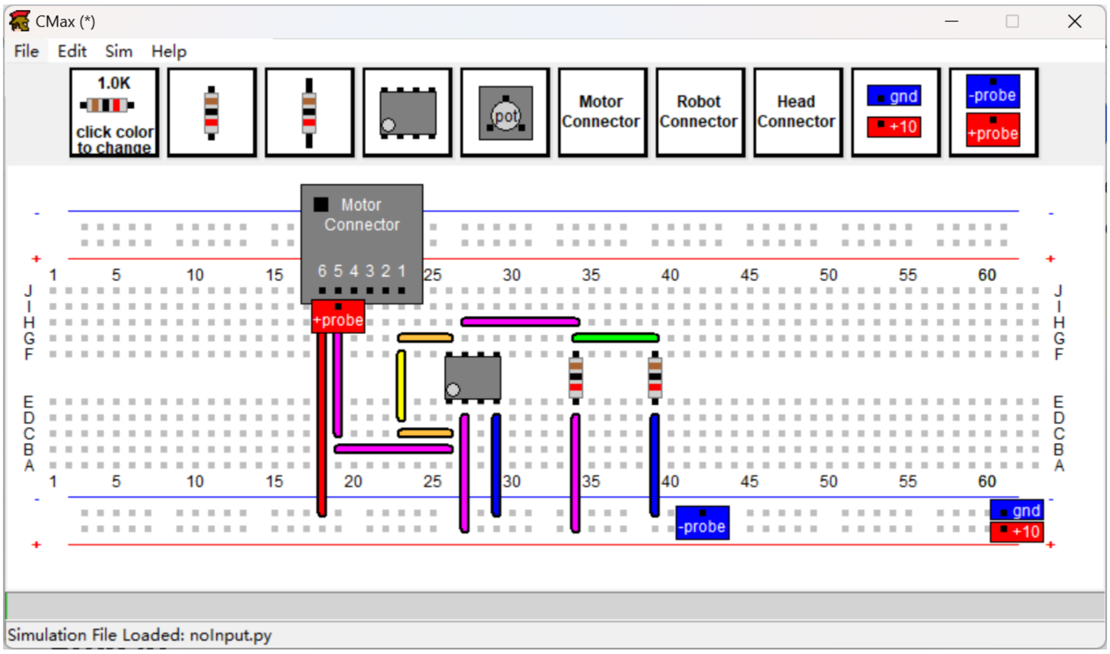
Check Yourself 2

Does the theory match the measurement in the previous part? Explain.

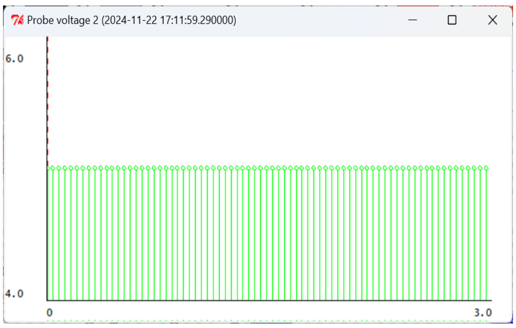
There is a certain error between the theoretical calculation and the measured value, but there is not much difference, because there are many factors, such as accuracy, temperature, and internal error of the motor.

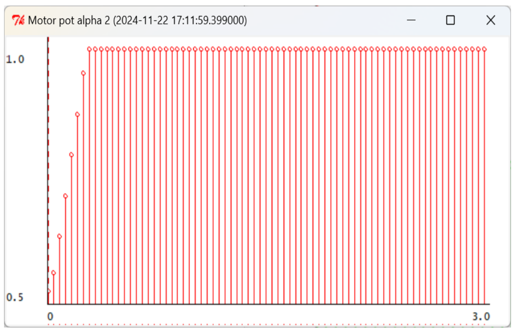
Step 5: Connect the circuit

Use CMax to lay out the buffered divider circuit as follows.

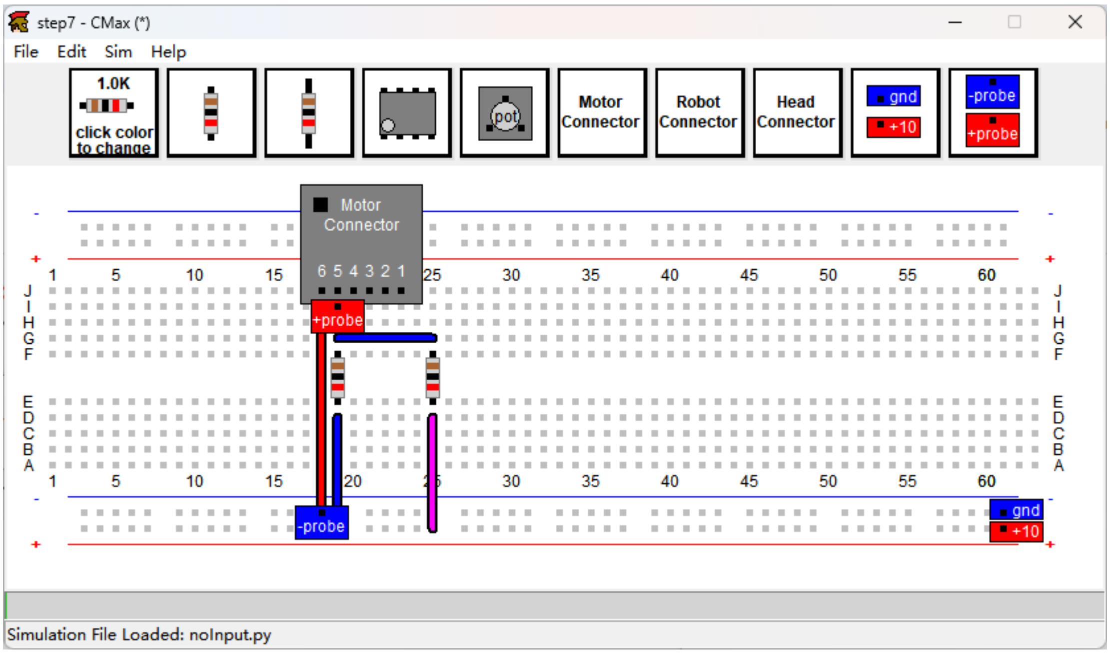


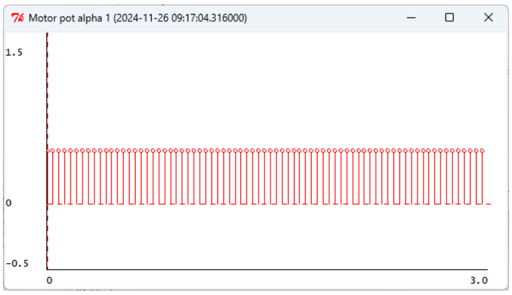
Running the simulation will produce several graphs, all of which have time on the x axis, and some other quantity on the y axis. Each signal is sampled at intervals of 0.02 seconds.

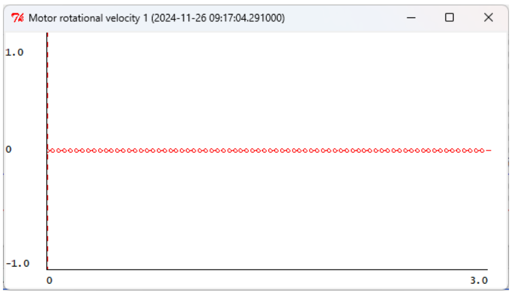


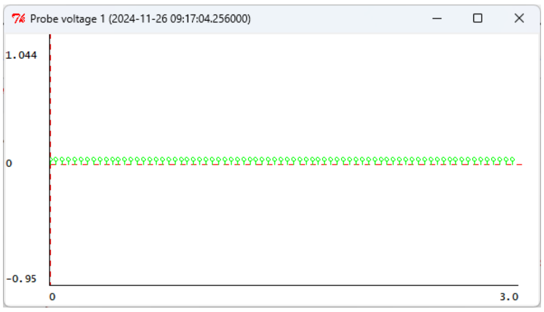


Use CMax to lay out the circuit without buffer as follows.









Step 6: Comparison

Check Yourself 3

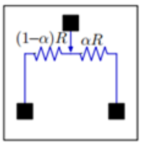
Compare the behaviors of the circuit with and without the buffer.

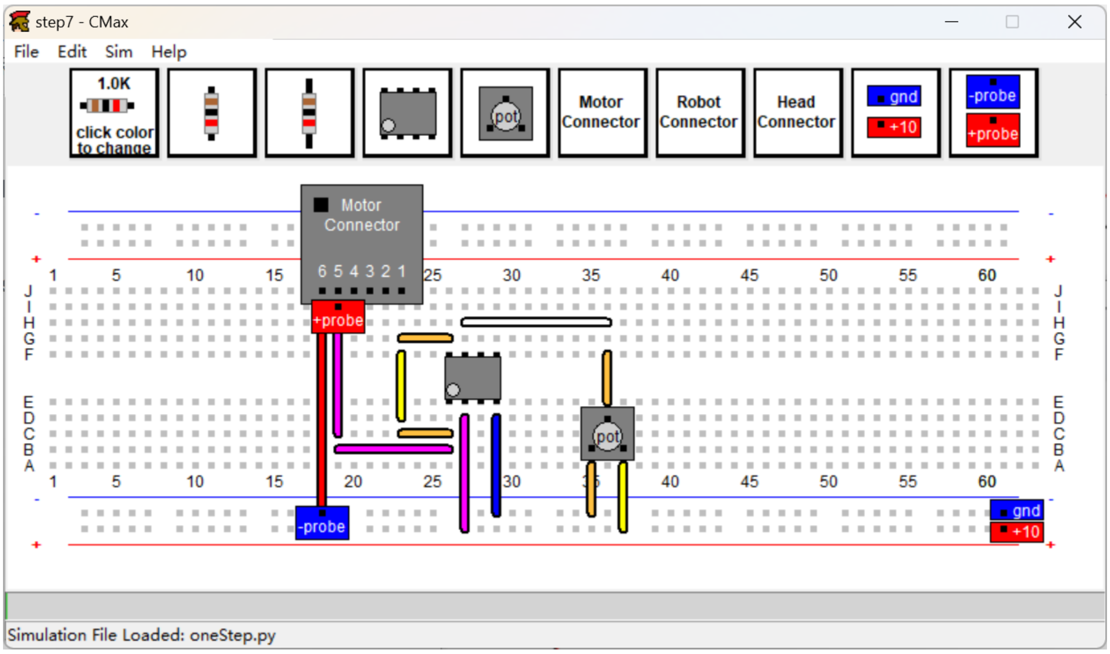
We can notice that the motor in the circuit without buffer doesn't react to the input. The green plot shows that the voltage of the motor is too low voltage to drive the motor. And the motor doesn't work in this condition.
On the other hand, in the circuit with the buffer, the motor works ideally because of the

stabilizing voltage function of the buffer. And the voltage between the motor is 5V stably.

Step 7:

Now, in CMax, replace the two resistors in the voltage divider with a potentiometer, so that when α = 0 (the pot is turned as far counter-clockwise as possible), the voltage across the motor is 0, and when α = 1, the voltage across the motor is 10.





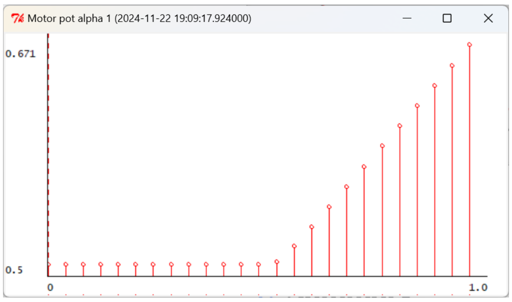
Load the simulation file oneStep.py, which specifies the input to the potentiometer.

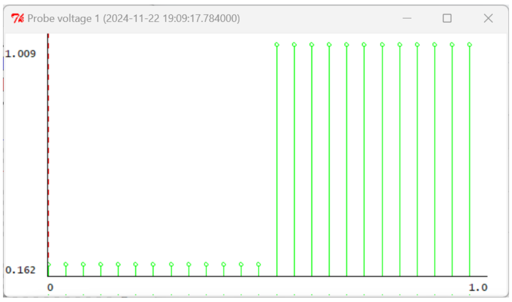
Check Yourself 4

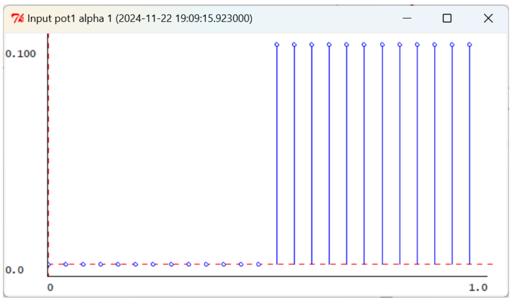
Make sure we understand the meaning of motor rotational velocity

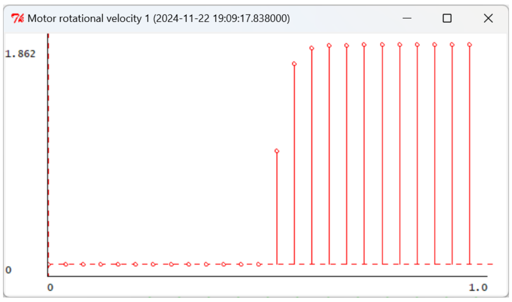
and motor pot alpha graphs. Save our CMax circuit and resulting plots.

As follows.









Step 8:

Replace the resistors in our physical circuit with a potentiometer, as in our CMax lawet.

Step the potentiometer through various settings (1/4 turn, 1/2 turn, 3/4 turn). Observe the behavior of the motor, and compare this behavior to our CMax simulation.

Checkoff1 & Wk.8.2.1:

Explain to a staff member the results of our experiments, with and without buffering. Compare the simulated behavior to the actual behavior of the circuit we built.

The circuit with the op amp could make the motor rotate.

Step 9: Design Bidirectional Speed Controller

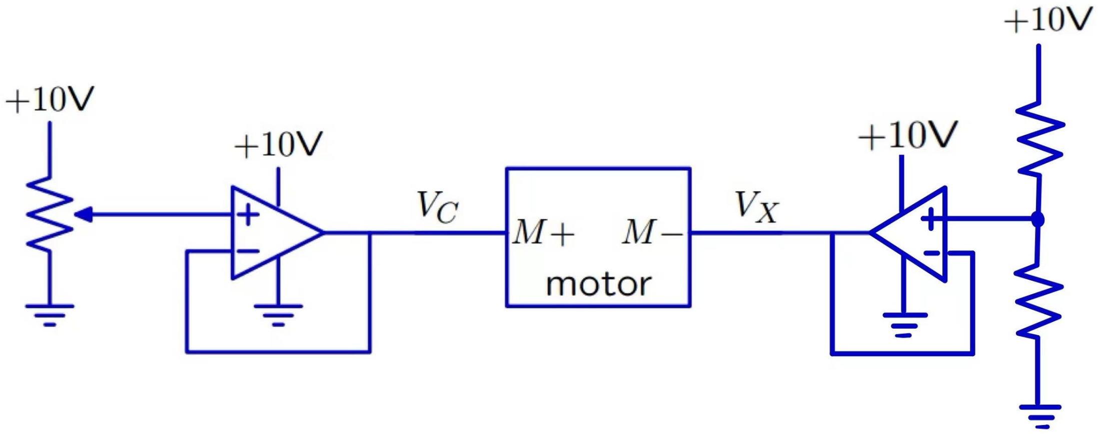
The key new component in the bidirectional speed controller is the voltage source VX. What value of VX gives the most symmetric (around 0) range of speeds for the motor?

VX =5V

Check Yourself 5

Can we implement VX with just a voltage divider? Explain.

No, we can't use a potentiometer to characterize Vx because it's very unstable. The new circuit is as follows.



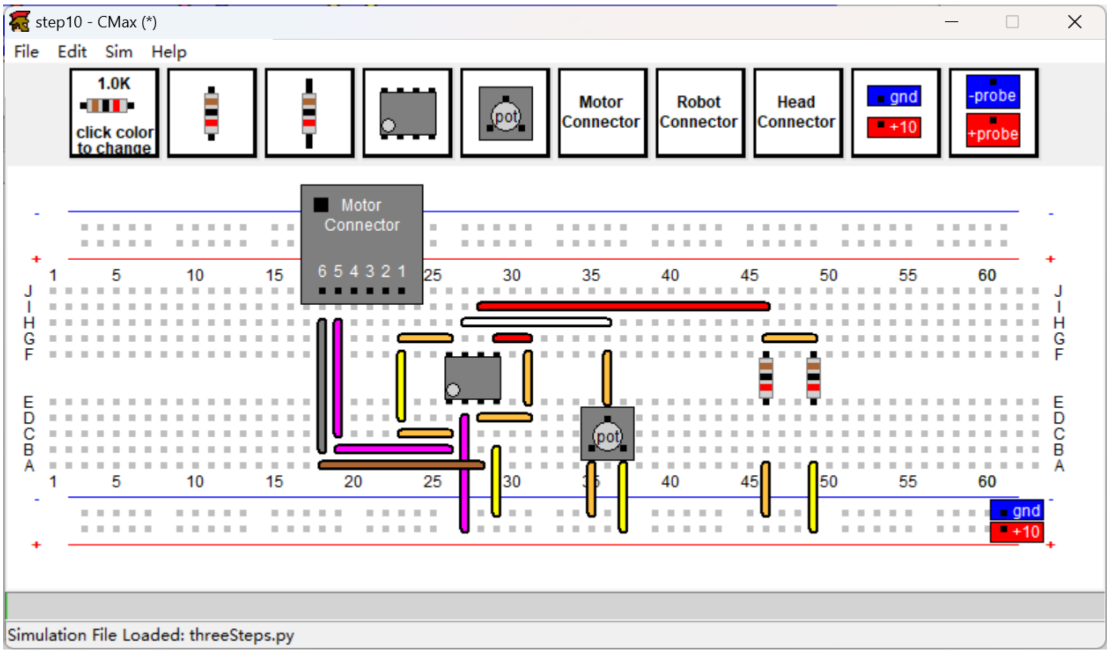
Step 10: Connect the circuit in Cmax

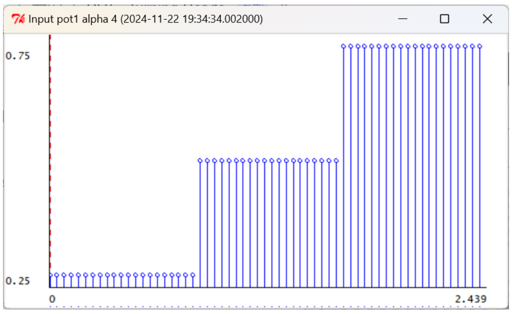
Use CMax to lay out our bidirectional control circuit.This circuit can be tested with the threeSteps.py simulation file.

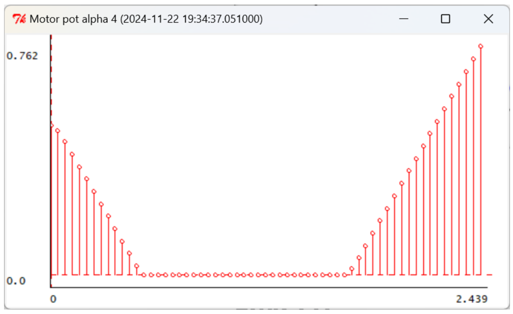
Checkoff2 & Wk.8.2.2:

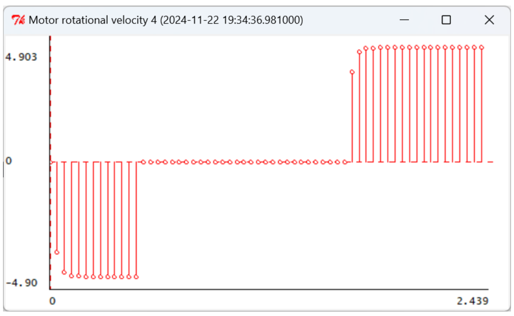
Demonstrate our working simulation. Explain the relation between motor speed and potentiometer angle. Demonstrate that we can generate both positive and negative speeds. Explain how our circuit accomplishes bidirectional speed control.

When the potentiometer is set to a specific angle, the motor reaches its maximum rotation speed. Adjusting the potentiometer angle not only alters the rotation speed but also changes the direction of rotation. By varying the relative magnitudes of Vc and Vx, we can control the motor's rotational direction. This behavior is evident in the simulated motor angle diagram, which displays both a gradual increase and a gradual decrease in the angle over time.









4 . Show me the light!

Objective:

Add feedback via a robot brain to control the motor in a robot head and steer its photoresistive eyes to point towards a light.

Resources:

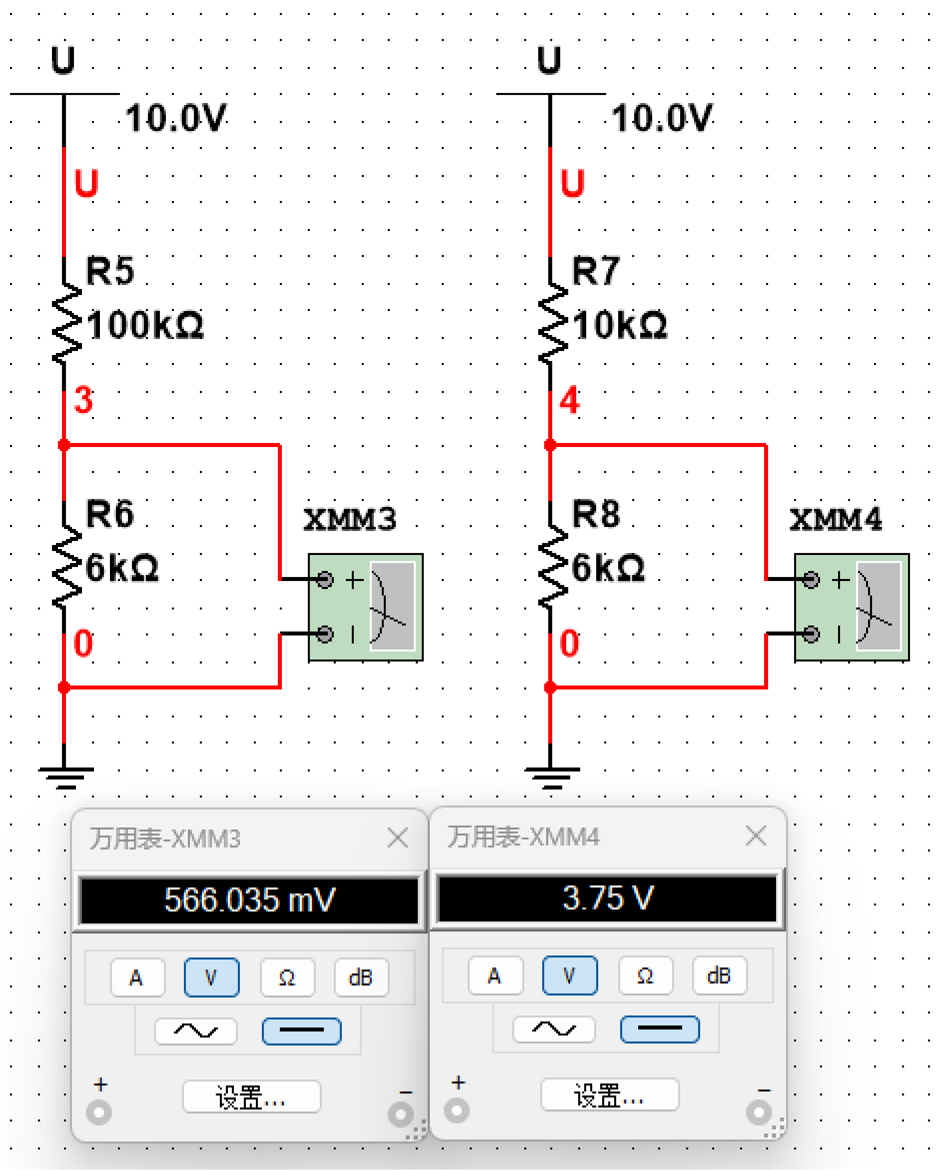
In addition to the equipment needed for the previous section, we also use:

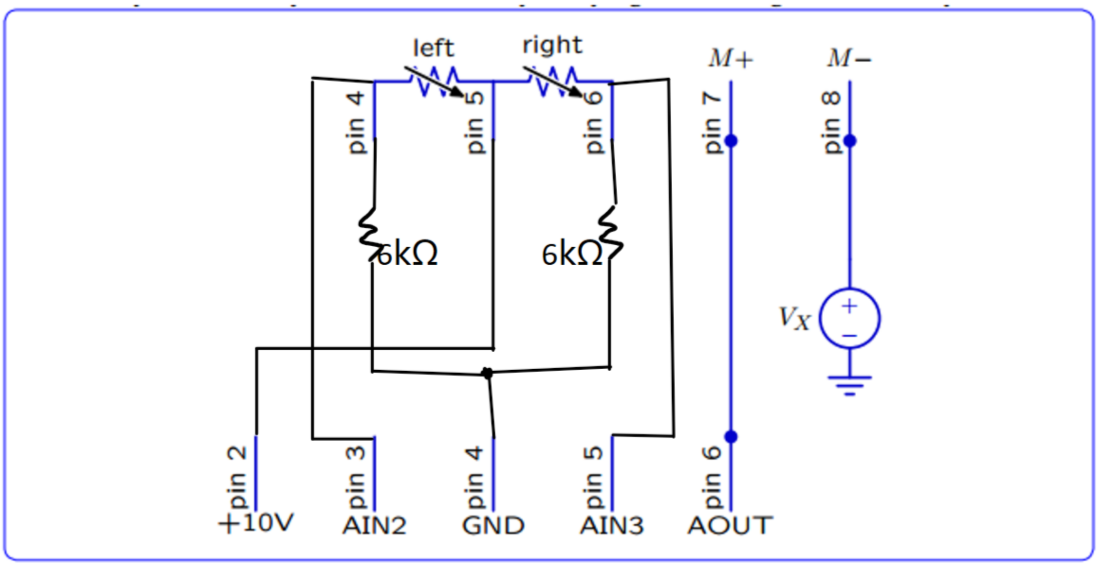
- Additional resistors and wires as needed
- turnHeadToLightBrain.py - Robot brain file with a proportional controller for providing

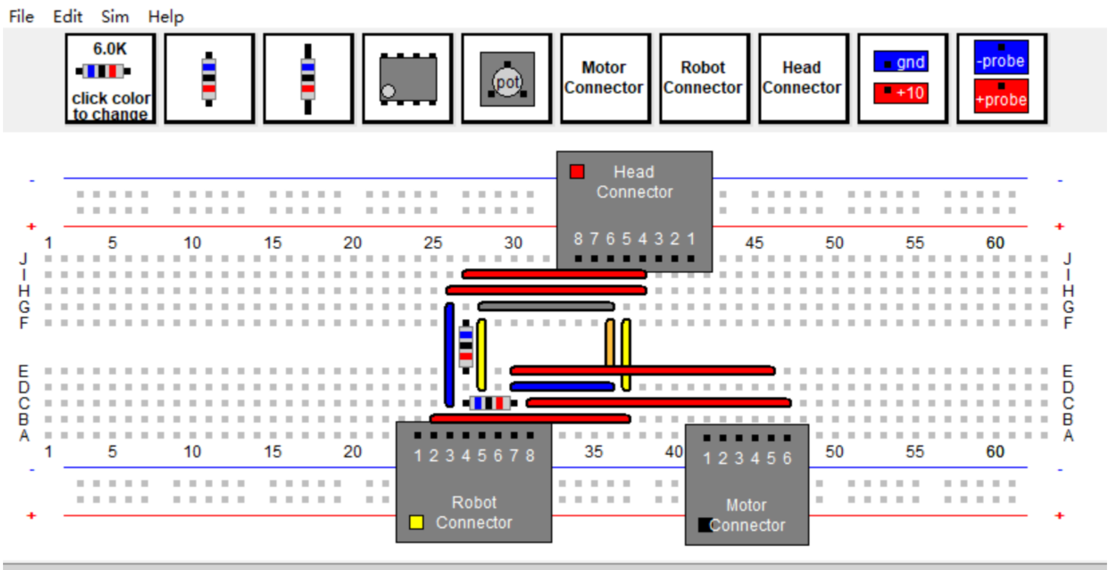
the motor feedback

We now construct a system which moves the Lego motor to steer the eyes (two photoresistors) on the robot head to locate and track a light. This combines the circuit designed for Design Lab7 to sense light, the proportional controller ideas studied in Design Lab 6 (and earlier), and ideas from the bi-directional controller.

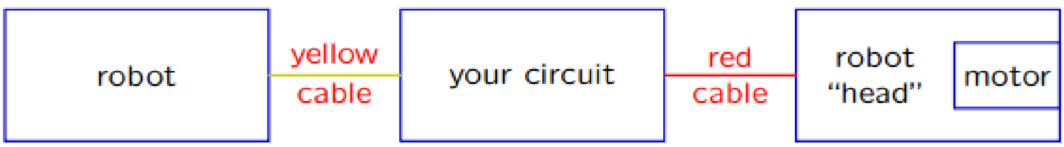
We add to this diagram your eye circuit from Step 16 of Design Lab 7.







Just as in Design Lab 7, here is how the whole system should be configured:



Step 11:

• Make sure that both the yellow cable and the read cable are connected to your circuit and head.

•Connect the black cable to motor connector on the head but do not connect it to the motor on the head yet.

•Turn the robot on.

•Start soar, select the turnHeadToLightBrain.py brain, and click Start.

•Turn on the light.

•Connect the black cable to the motor. If the head slams against the side, disconnect the cable immediately!

•Verify that the robot head follows as you direct the light from different incident angles.

Step 12:

• Start with the light at approximately 0.5 meters from the head. Change gain in the brain file to get the head to track the light as fast as possible without excessive oscillations. Keep track of the gain and save the plot.

• Move the light to about 1 meter away. What's the best gain/speed now? Save the plot.

• Modify the brain to have an additional delay.

• Find the gain with the fastest non-oscillatory response at 0.5 meters. Keep track of the gain and save the resulting plot.

• Repeat at 1 meter.

Checkoff3 & Wk.8.2.3:

Demonstrate our working light tracker. Show how fast we can make the motor smoothly track the position of the light. Explain the observed motor behavior in response to changes in gain, distance and delay.What limits the speed with which we can track the light?

Mr.Fang said "This week's experimental tasks are Design Lab 8 and Homework 3. Due to some technical issues with the small car, there are no requirements for the related real car experimental part (mainly the 4 Show me the light part, interested students can study it). The on-site acceptance will not be conducted, and other content should be completed carefully." Therefore the actual measurement is not required.

3. Summary

• The working voltage range of DC motor design is 0-10V, with a resistance value of 6.3 Ω and a minimum starting voltage of 0.4V. The motor speed is related to the applied voltage.When only using a resistor circuit to control the motor speed, the motor cannot rotate due to the voltage obtained from the motor voltage division being lower than the starting threshold. The theoretical calculation of motor voltage is similar to the measured value, but there are some errors due to factors such as measurement accuracy, temperature, and internal errors of the motor.

• After adding operational amplifier buffer, the motor can rotate. Replace the voltage divider resistor with a potentiometer, and adjust the motor voltage by changing the potentiometer angle to control the motor speed. In the experiment, the motor voltage was 0 when α=0 and 10V when α=1

• When the voltage source VX of the key component of the bidirectional speed controller is 5V, it can make the motor speed range most symmetrical. This voltage source needs to be constructed with an operational amplifier to achieve buffering and stability. By changing the relative size of Vc and Vx, the motor rotation direction and speed can be controlled

• By providing feedback to the motor through the proportional controller in the "turnHeadToLightBrain. py" of the robot, the rotation of the robot's head motor can be controlled to direct the photoresistor's eyes towards the light source. Changing the gain in the brain file can adjust the head tracking light source speed. The optimal gain varies at different distances from the light source, and increasing the delay will affect the response speed.